1. What is the pH of a solution prepared by dissolving 0.35 mol of CH$_3$NH$_3$Cl (methylamine hydrochloride) in 1.00 L of 1.1 M CH$_3$NH$_2$ (methylamine). The K$_b$ for methylamine is $4.4 \times 10^{-4}$.

A. 10.6  
B. 2.86  
C. 7.00  
D. 10.15  
E. 11.14

2. Element M reacts with oxygen to form an oxide with the formula MO. When MO is dissolved in water, the resulting solution is basic. Element 'M' is most likely:

A. Na  
B. Ba  
C. S  
D. N  
E. Al

3. Which of these oxides is most basic?

A. K$_2$O  
B. Al$_2$O$_3$  
C. CO$_2$  
D. MgO  
E. P$_2$O$_5$
4. Which equation represents a reaction that is **decreasing** in entropy as the reaction proceeds?

A. \( \text{CaCO}_3(s) \rightarrow \text{CaO(s)} + \text{CO}_2(g) \)
B. \( 2\text{C(s)} + \text{O}_2(g) \rightarrow 2\text{CO(g)} \)
C. \( \text{BaF}_2(s) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{F}^-(\text{aq}) \)
D. \( \text{N}_2\text{O}(g) + \text{NO}_2(g) \rightarrow 3\text{NO(g)} \)
E. \( 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O(ℓ)} \)

5. For a given reaction, \( \Delta H = +35.5 \text{ kJ/mol} \) and \( \Delta S = +83.6 \text{ J/K·mol} \). Assuming that \( \Delta H \) and \( \Delta S \) do not vary with temperature, the reaction is spontaneous __________.

A. at \( T < 425 \text{ K} \)
B. at \( T > 425 \text{ K} \)
C. at all temperatures
D. at \( T > 298 \text{ K} \)
E. at \( T < 298 \text{ K} \)

6. Which molecule below should have the highest gas-phase absolute entropy at 25 °C?

A. \( \text{N}_2 \)
B. \( \text{CO}_2 \)
C. \( \text{CO} \)
D. \( \text{CH}_4 \)
E. \( \text{CH}_3\text{CH}_3 \)

7. The solubility of manganese (II) hydroxide \( (\text{Mn(OH)}_2) \) is \( 2.2 \times 10^{-5} \text{ M} \). What is the \( K_{sp} \) of \( \text{Mn(OH)}_2 \)?

A. \( 2.2 \times 10^{-5} \)
B. \( 4.8 \times 10^{-10} \)
C. \( 1.1 \times 10^{-14} \)
D. \( 2.1 \times 10^{-14} \)
E. \( 4.3 \times 10^{-14} \)
8. Complete and balance the following half reaction in acid.

\[ \text{CrO}_2^-(aq) \rightarrow \text{CrO}_4^{2-}(aq) \]

How many electrons are needed and is the reaction an oxidation or reduction?

A. 2, oxidation  
B. 2, reduction  
C. 3, oxidation  
D. 4, reduction  
E. 6, oxidation

9. What is the half-reaction occurring at the anode in the balanced reaction shown below?

\[ 3\text{MnO}_4^-(aq) + 24\text{H}^+(aq) + 5\text{Fe(s)} \rightarrow 3\text{Mn}^{2+}(aq) + 5\text{Fe}^{3+}(aq) + 12\text{H}_2\text{O(ℓ)} \]

A. \( \text{MnO}_4^-(aq) + 8\text{H}^+(aq) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(aq) + 4\text{H}_2\text{O(ℓ)} \)  
B. \( 2\text{MnO}_4^-(aq) + 12\text{H}^+(aq) + 6\text{e}^- \rightarrow 2\text{Mn}^{2+}(aq) + 3\text{H}_2\text{O(ℓ)} \)  
C. \( \text{Fe(s)} \rightarrow \text{Fe}^{3+}(aq) + 3\text{e}^- \)  
D. \( \text{Fe(s)} \rightarrow \text{Fe}^{2+}(aq) + 2\text{e}^- \)  
E. \( \text{Fe}^{2+}(aq) \rightarrow \text{Fe}^{3+}(aq) + \text{e}^- \)

10. What is the value of \( \Delta G^\circ \) for this reaction at 25 °C.

\[ \text{N}_2 (g) + 3\text{H}_2 (g) \rightleftharpoons 2\text{NH}_3 (g) \quad K_{eq} = 5.0 \times 10^8 \]

A. +22 kJ/mol  
B. –4.2 kJ/mol  
C. –25 kJ/mol  
D. –50 kJ/mol  
E. –490 kJ/mol
11. The drawing below represents a buffer composed of equal concentrations of a weak acid HX and its conjugate base X\(^-\).

Which drawing depicts schematically the composition of the solution after the buffer is diluted by adding pure water?

A. 1  
B. 2  
C. 3  
D. 1 and 2  
E. 1 and 3

12. When the following oxidation/reduction reaction is balanced in acid solution, what is the coefficient of H\(_2\)O (\(\ell\))?

\[
\text{NO}_2^-(aq) + \text{Cr}_2\text{O}_7^{2-}(aq) \rightarrow \text{Cr}^{3+}(aq) + \text{NO}_3^-(aq)
\]

A. 7  
B. 5  
C. 0  
D. 3  
E. 4

Go on to the next page
13. Consider the following solutions:
   1. 100 mL of 0.2 M CH₃COOH + 100 mL 0.4 M NaOH
   2. 100 mL of 0.1 M CH₃COOH + 100 mL 0.1 M NaOH
   3. 100 mL of 0.2 M CH₃COOH + 100 mL 0.1 M NaOH
   4. 100 mL of 0.3 M HCl + 100 mL 0.2 M NaOH

   The solutions which will be buffers are,
   A. 1, 2, and 3
   B. 4 only
   C. 3 only
   D. 1 only
   E. 2 only

14. 50.0 ml of 0.274M KOH(aq) is added to 22.5 ml of 0.413M HNO₃(aq) and a reaction occurs. What is the pH of the final mixture?
   A. 0.562
   B. 1.44
   C. 7.0
   D. 13.4
   E. 12.8

15. Which of the following is not likely to increase the molar solubility of silver carbonate (Ag₂CO₃) in water?
   (i) Adding NH₃
   (ii) Adding HCl
   (iii) Adding Na₂CO₃
   A. (i) only
   B. (ii) only
   C. (iii) only
   D. (i) and (iii)
   E. (ii) and (iii)
16. Calculate the molar solubility at 25 °C of silver chromate, Ag₂CrO₄, in a solution that contains 0.100 M AgNO₃. The Ksp for Ag₂CrO₄ is 9.0 × 10⁻¹₂ at 25 °C.

A. 1.3 × 10⁻⁴ M  
B. 9.7 × 10⁻⁴ M  
C. 3.0 × 10⁻⁵ M  
D. 8.2 × 10⁻⁹ M  
E. 9.0 × 10⁻¹⁰ M

17. Consider the following table of thermodynamic data. All values are tabulated for 25 °C.

<table>
<thead>
<tr>
<th>Substance</th>
<th>ΔG°ᵢ (kJ/mol)</th>
<th>S° (J/mol·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₂H₂ (g)</td>
<td>209</td>
<td>201</td>
</tr>
<tr>
<td>C₂H₄ (g)</td>
<td>68</td>
<td>219</td>
</tr>
<tr>
<td>C₂H₆ (g)</td>
<td>–33</td>
<td>230</td>
</tr>
<tr>
<td>H₂ (g)</td>
<td>0</td>
<td>131</td>
</tr>
<tr>
<td>H₂O (g)</td>
<td>–229</td>
<td>189</td>
</tr>
<tr>
<td>C₂H₅OH (l)</td>
<td>–175</td>
<td>161</td>
</tr>
</tbody>
</table>

What is the value of ΔH° for the reaction described below? Assume the reaction is performed at 25°C.

\[ \text{C}_2\text{H}_2 (g) + 2\text{H}_2 (g) \rightarrow \text{C}_2\text{H}_6 (g) \]

A. –173 kJ  
B. 236 kJ  
C. –311 kJ  
D. –248 kJ  
E. There is insufficient information to determine this.
18. What is $\Delta G^\circ$ for the reaction, $\text{Pb(s) + 2Ag}^+ (aq) \rightarrow \text{Pb}^{2+} (aq) + 2\text{Ag(s)}$?
   A. $-89.7 \text{ kJ}$
   B. $-334 \text{ kJ}$
   C. $-179 \text{ kJ}$
   D. $-129 \text{ kJ}$
   E. $-167 \text{ kJ}$

19. A beaker contains 50 ml of 0.15M $\text{NH}_3 (aq)$. It is titrated with 0.15M $\text{HNO}_3 (aq)$ at 25°C. $K_b$ for $\text{NH}_3 = 1.8 \times 10^{-5}$. What is the pH at the equivalence point of this titration?
   A. 4.74
   B. 5.19
   C. 8.81
   D. 9.25
   E. 12.9

20. Calculate the concentration of $\text{Cu}^{2+} (aq)$ in 1L of a solution that contains a total of $1 \times 10^{-3}$ mol of Cu(II) ion and that is 0.10 M in $\text{NH}_3$. ( $K_f$ for $[\text{Cu(NH}_3]^{2+}] = 5 \times 10^{12}$)
   A. $1 \times 10^{-3}$ M
   B. $5 \times 10^5$ M
   C. $2 \times 10^{18}$ M
   D. $2 \times 10^{-12}$ M
   E. $2 \times 10^{-15}$ M
21. 100.0 mL of 0.050 M \( \text{Na}_2\text{SO}_4 \) is added to 100.0 mL of 0.0025 M \( \text{AgNO}_3 \) at 25°C. The \( K_{sp} \) for \( \text{Ag}_2\text{SO}_4 \) is \( 1.5 \times 10^{-5} \) at 25°C, and \( \text{NaNO}_3 \) is very soluble in water at 25°C. Which one of the following statements is true?

A. \( \text{Ag}_2\text{SO}_4 \) will precipitate and extra \( \text{Ag}^+ \text{(aq)} \), but no \( \text{SO}_4^{2-} \text{(aq)} \), will be present after precipitation.

B. \( \text{Ag}_2\text{SO}_4 \) will precipitate and extra \( \text{SO}_4^{2-} \text{(aq)} \), but no \( \text{Ag}^+ \text{(aq)} \), will be present after precipitation.

C. \( \text{Ag}_2\text{SO}_4 \) will precipitate and extra \( \text{SO}_4^{2-} \text{(aq)} \) and \( \text{Ag}^+ \text{(aq)} \) will be present after precipitation.

D. \( \text{Ag}_2\text{SO}_4 \) will precipitate, but there will be no extra \( \text{SO}_4^{2-} \text{(aq)} \) or \( \text{Ag}^+ \text{(aq)} \) present after precipitation.

E. \( \text{Ag}_2\text{SO}_4 \) will not precipitate from solution under these conditions.

22. What is the equilibrium constant for the neutralization reaction of \( \text{HClO} \) with a \( \text{KOH} \) solution at 25°C? (\( K_a \) for \( \text{HClO} \) is \( 3.0 \times 10^{-8} \))

\[
\text{HClO(aq) + KOH(aq)} \rightleftharpoons \text{KClO(aq) + H}_2\text{O(l)}
\]

A. \( 3.0 \times 10^{-8} \)

B. \( 3.3 \times 10^{-7} \)

C. \( 3.0 \times 10^6 \)

D. \( 3.3 \times 10^{21} \)

E. \( 3.0 \times 10^{-22} \)
23. Calculate $E^\circ$ for a cell in which the overall reaction is:

$$\text{O}_2(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{H}_2\text{O}_2(\text{aq})$$

A. $-0.50 \text{ V}$  
B. $-0.70 \text{ V}$  
C. $+0.68 \text{ V}$  
D. $+1.10 \text{ V}$  
E. $+2.46 \text{ V}$

24. What is the value of $E_{\text{cell}}$ for the reaction below, when the concentration of $\text{Zn}^{2+}(\text{aq})$ is $0.00020 \text{ M}$ and the concentration of $\text{Pb}^{2+}(\text{aq})$ is $1.0 \text{ M}$?

$$\text{Pb}^{2+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Pb}(\text{s})$$

A. $0.52 \text{ V}$  
B. $0.85 \text{ V}$  
C. $0.41 \text{ V}$  
D. $0.74 \text{ V}$  
E. $0.63 \text{ V}$

25. Arrange the following agents in order of increasing oxidizing power (weakest oxidizing agent to strongest oxidizing agent):

<table>
<thead>
<tr>
<th>$\text{H}^+$</th>
<th>$\text{Fe}^{2+}$</th>
<th>$\text{H}_2\text{O}_2$</th>
<th>$\text{Cr}^{3+}$</th>
<th>$\text{Sn}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. $\text{H}^+ &lt; \text{Fe}^{2+} &lt; \text{H}_2\text{O}_2 &lt; \text{Cr}^{3+} &lt; \text{Sn}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. $\text{Sn} &lt; \text{H}_2\text{O}_2 &lt; \text{H}^+ &lt; \text{Fe}^{2+} &lt; \text{Cr}^{3+}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. $\text{Cr}^{3+} &lt; \text{Sn} &lt; \text{H}_2\text{O}_2 &lt; \text{Fe}^{2+} &lt; \text{H}^+$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. $\text{Cr}^{3+} &lt; \text{Fe}^{2+} &lt; \text{H}^+ &lt; \text{H}_2\text{O}_2 &lt; \text{Sn}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. $\text{Sn} &lt; \text{Cr}^{3+} &lt; \text{Fe}^{2+} &lt; \text{H}^+ &lt; \text{H}_2\text{O}_2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

END OF EXAM
Form A

1. E
2. B
3. A
4. E
5. B
6. E
7. E
8. C
9. C
10. D
11. B
12. E
13. C
14. E
15. C
16. E
17. C
18. C
19. B
20. D
21. E
22. C
23. C
24. D
25. E